Remote Sensing of Aerosol Composition From CO_2 Lidar Backscatter

Maurice A. Jarzembski/ES41
205–922–5964
E-mail: maurice.jarzembski@msfc.nasa.gov

A high resolution technique for remote sensing atmospheric aerosol composition from aerosol backscatter measurements is being developed using a new infrared, wavelength-tunable, coherent, continuous-wave, focused, CO_2 Doppler lidar to be used as a "spectrometer." Such an instrument, applicable both for airborne as well as ground-based operations, has not been developed before.

The basis of this new instrument rests on the spectral response of backscatter in the middle infrared (9 to 11 μm) regime which is extremely sensitive to aerosol composition. This is due to material resonance anomalies in absorption which causes peaks in backscatter spectrum at specific infrared wavelengths, characteristic of complex refractive indices of aerosol composition. As an example, ammonium sulfate has a peak at the 9.1-μm wavelength but not at the 10.6-μm wavelength which gives rise to a difference in backscatter of a factor of 9 for typical atmospheric particle diameter <0.8 μm found in the middle and upper troposphere. Using this fact, a new method is being developed to infer aerosol composition from the measured wavelength-dependent backscattered signal using a rapid-tunable, multiwavelength continuous wave (CW) CO_2 lidar. This would allow identification of climatically significant atmospheric aerosols such as sulfates, sulfuric acid, dust, sea salt, water, and ice which have a specific signature in the 9 to 11 μm from their absorption spectra and hence backscatter spectra. Multiple wavelength tunability will also enable distinction between hygroscopic and nonhygroscopic aerosols, enabling identification of cloud condensation nuclei (CCN). This characterization is important for understanding and modeling of cloud microphysics, precipitation and hydrological cycle. This new application of a single lidar as a "spectrometer" for remotely inferring aerosol compositions offers many important advantages over existing aerosol chemistry sensors:

- It samples aerosols remotely, thereby, avoiding any physical and chemical contamination that are associated with aspirated samples;
- It provides much larger sample volumes with fewer particle count statistics problems than particle counters; and
- It offers large-scale atmospheric sampling with unprecedented high-spatial/temporal resolution (~5 sec ~1 km) even in quite low-aerosol concentrations, and could give even finer resolution in higher concentrations.

The proof of concept has been recently demonstrated with the comparison of dual-wavelength lidar backscatter data obtained by two NASA/MSFC CO_2 Doppler lidars operating at wavelengths 9.1 and 10.6 μm to identify sulfate aerosols.[1] The validity of inferring aerosol composition from the relative backscatter at several wavelengths is shown in figure 157. Figure 157 shows atmospheric measurements during the global backscatter experiment (GLOBE II) in 1990 taken at an 8-km altitude in transit from Tokyo, Japan to Honoulu, Hawaii. The backscatter ratio β_R is defined as the ratio of backscatter β at the lidar wavelengths 9.1 and 10.6 μm, given by $\beta_R = \beta(9.1)/\beta(10.6)$. For $\beta_R > 2$ indicates presence of sulfate composition. The direct lidar measured β_R is compared with modeled β_R using simultaneously measured aerosol microphysics data by a laser optical particle counter (LOPC). The state-of-the-art LOPC aerosol counter measures real-time aerosol distribution and composition from which β_R can be modeled using Mie theory, the electromagnetic scattering from a dielectric sphere. The modeled LOPC β_R and measured lidar β_R agree very well, showing overall similar trends. In view of the major differences in the lidar versus aerosol counter instrumentation and sampling, this reasonably good agreement indicates that measurements of composition from LOPC can be used to predict β_R; thus inversely measured lidar β_R can lead to good inference of aerosol composition.[1]

There is a critical need to determine aerosol composition variability on a regional as well as global scale as it can have major impact on the Earth's radiative balance,

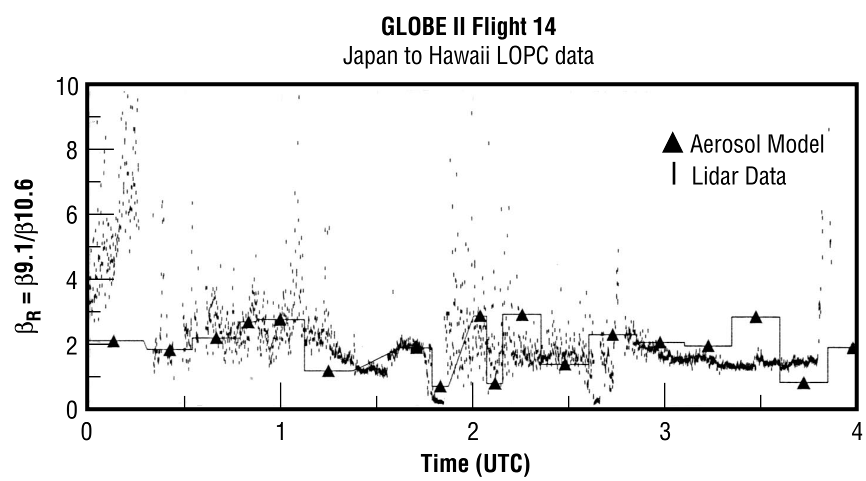

FIGURE 157.—Time series of backscatter ratio $\beta_R = \beta\,(9.1)/\beta\,(10.6)$ from lidar data in comparison with that obtained from the modeled results from the laser optical particle counter (LOPC).

affecting climate. The emphasis within NASA on remote sensing of various atmospheric constituents motivates a deeper understanding of composition of atmospheric aerosols for better inputs to circulation models. This wavelength-tunable lidar provides an innovative technology for application of a lidar in remotely inferring atmospheric aerosol composition on a large scale with very high spatial and temporal resolution. This will thus strengthen NASA's role on characterization of climatically significant aerosols.

[1]Srivastava, V.; Bowdle, D.A.; Jarzembski, M.A.; Rothermel, J.; Chambers, D.M.; and Cutten, D.R.: "High Resolution Remote Sensing of Sulfate Aerosols From CO_2 Lidar Backscatter." Geophysical Research Letter, 22, pp. 2373–2376, 1995.

Sponsor: Center Director's Discretionary Fund

Biographical Sketch: Dr. Maurice Jarzembski earned a Ph.D. in physics from New Mexico State University and has been with MSFC for almost 8 years. He is a physicist within the Earth System Science Division of MSFC Science and Engineering Directorate and is in the field of remote sensing using lidars.